

The University of Chicago

FACTORS IN RAT LEARNING
AN ANALYSIS OF THE INTERCORRELATIONS
BETWEEN 34 VARIABLES

A DISSERTATION SUBMITTED TO THE
FACULTY OF THE DIVISION OF THE
BIOLOGICAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF PSYCHOLOGY
1936

By
CHARLES L. VAUGHN

Private Edition, Distributed by
THE UNIVERSITY OF CHICAGO LIBRARIES
CHICAGO, ILLINOIS

Reprinted from
COMPARATIVE PSYCHOLOGY MONOGRAPHS
Vol. 14, No. 3, July, 1937

The University of Chicago

FACTORS IN RAT LEARNING
AN ANALYSIS OF THE INTERCORRELATIONS
BETWEEN 34 VARIABLES

A DISSERTATION SUBMITTED TO THE
FACULTY OF THE DIVISION OF THE
BIOLOGICAL SCIENCES IN CANDIDACY FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF PSYCHOLOGY
1936

By
CHARLES L. VAUGHN

Private Edition, Distributed by
THE UNIVERSITY OF CHICAGO LIBRARIES
CHICAGO, ILLINOIS

Reprinted from
COMPARATIVE PSYCHOLOGY MONOGRAPHS
Vol. 14, No. 3, July, 1937

ACKNOWLEDGMENT

These experiments were conducted in the laboratory of the Department of Psychology of the University of Chicago. The writer is deeply indebted to Professors K. S. Lashley and L. L. Thurstone for many stimulating suggestions in this work. Professor Lashley supervised the project from inception until completion, and Professor Thurstone served as a statistical advisor.



FACTORS IN RAT LEARNING: AN ANALYSIS OF THE INTERCORRELATIONS BETWEEN 34 VARIABLES

CHARLES L. VAUGHN

Wayne County Training School, Northville, Michigan

CONTENTS

I. Introduction.....	1
II. Apparatus and Procedures.....	3
III. Variables and Intercorrelations.....	15
IV. Factor Analysis.....	17
V. Discussion.....	29
References.....	38
Appendix.....	39

TABLES

I. Dates at Which Animals Started on Various Tests.....	3
II. Intercorrelations Between Variables.....	18, 19
III. Centroid Matrix and Communalities.....	21
IV. Transformation Matrix.....	28
V. Factorial Matrix.....	29
VI. Expected and Actual Weightings of Variables if I is General Speed Factor.....	30

ILLUSTRATIONS

1. Diagrams of Apparatus.....	6
2. Diagrams of Apparatus.....	8
3. Diagrams of Apparatus.....	12
4. Distribution of Eighth Factor Residuals.....	22
5. Factor Plots.....	23
6. Factor Plots.....	24
7. Factor Plots.....	25
8. Factor Plots.....	26
9. Factor Plots.....	27
10. Factor Plots.....	28
11. Distributions of Raw Scores.....	40
12. Distributions of Raw Scores.....	41

I. INTRODUCTION

Numerous measures of variables such as learning ability, motivation, wildness, persistence, and general activity have been

devised in animal work; but little attempt has been made to determine what these commonly-used tests actually do measure. This study was designed as a preliminary attempt to discover whether we can disclose by the factoring methods what they do test and what they have in common.

In using the present factor methods, one assumes that an animal's score on a test is a linear function of its score on a complex of factors (18), that is,

$$S_{ji} = a_{j1}x_{1i} + a_{j2}x_{2i} + a_{j3}x_{3i} + \cdots + a_{jq}x_{qi},$$

in which S_{ji} represents the standard score of individual i in test j , the x 's represent standard scores in the q statistically independent arbitrary reference factors, and the a 's represent factor loadings in the tests. With this assumption made, the problem then becomes one of determining the parameters, a_{jq} , of the equation so that they are psychologically meaningful.

Dunlap's (2) study with chicks, Thorndike's (17) and McCulloch's (11) with rats, and other intercorrelation studies with animal subjects, extensively reviewed by Thorndike (17), bear directly upon the problem of this experiment; but newer developments in factor theory make it seem advisable to postpone discussion of their results until further analysis has been made. It is doubtful, however, whether these earlier studies will reveal more than a tentative list of factors which are operative in producing the scores on the various tests. Those studies, as well as this one, will merely serve as a basis for follow-up work along lines that might be expected to yield more definite results.

The tests used in the present study were chosen in an attempt to isolate as many factors as possible with previously used animal tests. Those already in use were selected in order to avoid setting up for the present at least, new and perhaps entirely unreliable measures of hypothetical functions. The following discussion will be divided into four sections: Apparatus and Procedure, Variables and Intercorrelations, Factor Analysis, and Discussion.

II. APPARATUS AND PROCEDURE

Subjects

The subjects for the experiment consisted of eighty male rats, started in six groups of 12 each and one of eight, not all of which completed training. The animals were fourth to sixth generation offspring of a cross between rats from the Wistar stock and trapped wilds, taken at random from the colony of the psychology laboratory of The University of Chicago. However, runts and

TABLE I
Dates at which animals started on various tests

RAT NUMBERS*	WILDNESS	ACTIVITY	STRAIGHTAWAY	FIRST RIGHT GOING	LEFT GOING	SECOND RIGHT GOING	MULTIPLE - T MAZE	RECTANGULAR MAZE	PROBLEM BOX	LIGHT DISCRIMINATION	MAIER TEST	PERSEVERANCE
1-12	12-11 '33	12-15 '33	1-6 '34	1-9 '34	1-15 '34	Varied	2-7 '34	2-28 '34	3-16 '34	4-11 '34	—	Varied
13-20	3-16 '34	3-20 '34	4-12 '34	4-17 '34	4-29 '34	Varied	5-16 '34	6-8 '34	6-26 '34	7-21 '34	—	Varied
21-32	4-9 '34	4-13 '34	5-7 '34	5-11 '34	5-26 '34	Varied	6-20 '34	7-21 '34	8-8 '34	8-24 '34	—	Varied
33-44	10-14 '34	10-18 '34	11-9 '34	11-14 '34	11-26 '34	Varied	12-22 '34	1-15 '35	2-1 '35	2-25 '35	Varied	Varied
45-56	11-4 '34	11-8 '34	11-30 '34	12-5 '34	12-17 '34	Varied	1-13 '35	2-5 '35	2-17 '35	3-12 '35	Varied	Varied
57-68	12-2 '34	12-5 '34	12-29 '34	1-1 '35	1-15 '35	Varied	2-7 '35	3-1 '35	3-17 '35	4-7 '35	Varied	Varied
69-80	12-18 '34	12-22 '34	1-15 '35	1-18 '35	1-30 '35	Varied	2-21 '35	3-14 '35	3-30 '35	4-21 '35	Varied	Varied

* Some animals died during experiment.

others obviously physically defective were excluded. The total was composed of about thirty litters. The ages of the animals when taken from the colony ranged between 79 and ninety days. The dispersion increased somewhat during the period of experimentation.

General procedures

The animals were started at seven different dates. They were taken from the breeding cages on the following days: December

11, 1933, and March 16, April 9, October 10, November 1, December 1, and December 18, 1934. Table I gives the approximate dates at which each group started on each test. As the experimental period lasted five months, initial and daily weight records, from the third day on, were taken to prevent any marked inanition or overfeeding.

Temperature control was by thermostat. The regulator was set at 78°, but the temperature ranged between 75 and 95° in the room during the period from December 11, 1933, until June 1, 1935. However, while the animals were in the activity cages, and most of the other time, the temperature was constant at 78°. Ceiling lights (with 100 watt bulbs) served for illumination of the room during experimentation.

The incentive on every task was bread and milk. The animals were fed during and after the completion of each day's runs. In general, after finishing the various tasks, they were given a three-day rest period with lettuce and meat in the home cages. Exceptions to this rule will be noted in the section for specific procedures. The writer cared for the animals and ran them through all the tests.

Apparatus and specific procedures

The apparatus for the experiment involved ten different set-ups. They were, in order of use, Wildness Tunnel, Activity Cage, Straightaway, Simple Maze, the 12-cul-de-sac Multiple-T Maze, Rectangular Maze, Double Platform Problem Box, Multiple-Light Discrimination Box, a modification of Maier's "reasoning" test, and Perseverance Box. The animals were trained for three habits on the Simple Maze. In general, the scores taken were total time, time in errors, errors, and trials to meet a criterion. Description of the apparatus and of specific procedures follows.

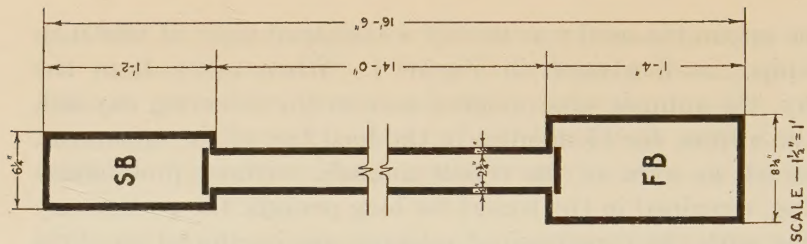
Wildness Tunnel. This apparatus is the same as that devised and validated as one measure of wildness by Stone (16). He found that time in the tunnel differentiates trapped wilds and second generation crosses between wilds and tame albinos from tame albinos. The two former groups, and especially the first, remain in the tunnel much longer than the last.

The apparatus used was merely a U-shaped piece of four-inch stovepipe, as illustrated in Figure 1. When taken from the colony, the animals were weighed and on the following day fed, four at a time, for 15 minutes in the food box of the apparatus. Inasmuch as some of the tryout animals, without preliminary feeding, remained in the tunnel for long periods, the preliminary feeding with the experimental subjects was continued for three days to lessen the time for giving the test. On the fourth day each animal was placed in the entrance (S) of the tunnel and allowed to remain there until fully entering the food box. The score recorded was the time elapsing between placement in the entrance and the exit into the food box. Animals remaining in the tunnel for 200 seconds were taken out and that score recorded for them. Time was taken with a Brenet stop watch. The experimenter stood at all times in front of the exit.

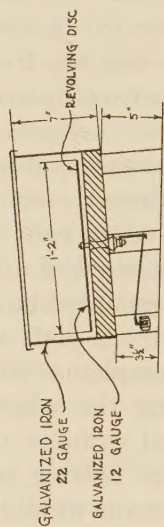
Activity cages. The activity cage consisted of a 14-inch sheet metal disc, tilted at a slight angle and mounted on the axle of a bicycle hub. The axle was attached by a shaft and eccentric to a Veeder counter, which registered complete revolutions of the wheel in either direction. Surrounding the wheel, with one-fourth inch intervening, was a vertical cylinder of galvanized sheet iron. A removable cover of wire netting prevented the animal's escape. The rat could obtain water at all times through a tube leading from an inverted glass jar placed on the cover of the cage. A set of 12 of these cages was mounted on three shelves of a rack. Figure 1 shows the design of the apparatus.

The animals were placed in the cages immediately after being given the trial in the Wildness Tunnel. They remained in these cages 14 days, being taken out and placed in their home cages for feeding at a given time each day. They were allowed to eat for one hour and a half. After being fed, each animal was placed in a cage different from the one in which it had been the preceding day. For instance, on the first day Rat 1 was placed in Cage 1, on the second day in Cage 2, on the third day in Cage 3, and so on. Bread and milk, with lettuce and meat on the seventh day, was the diet.

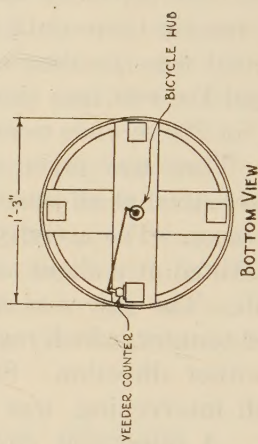
The animals were allowed nine days to get accustomed to the



STRAIGHTAWAY



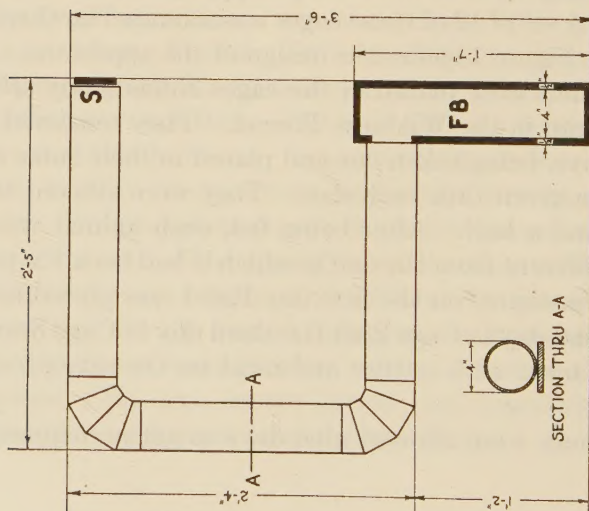
SIDE SECTIONAL VIEW



BOTTOM VIEW

SCALE $\sim \frac{1}{8}" = 1"$

ACTIVITY CAGE

SCALE $\sim \frac{1}{2}" = 1'$

WILDNESS TUNNEL

FIG. 1. DIAGRAMS OF APPARATUS

cages. This procedure is in accord with that of Shirley (13) with a similar apparatus. For the present study records were kept of the total activity, days 9 to 14. These scores, although utilized primarily as a measure of the spontaneous activity of the rat, are undoubtedly influenced by various factors, an important one of which is probably bodily endurance.

Straightaway. The Straightaway, used here to measure the rat's speed of running, was 14 feet long and of the design commonly used for preliminary training in maze experiments. The starting box, with a release door, was at one end of the path; and the food box, with a trap door, at the other. The measurements are shown in Figure 1.

In general, three days of rest were given the animals after they were taken from the activity cages. During this period, they were fed meat and lettuce besides the regular bread and milk diet. The animals were then given three days of preliminary feeding, 15 minutes a day in the food box of the Straightaway. On the fourth and fifth days, they were given five trials on the Straightaway and allowed to eat for 15 minutes thereafter. The sixth day they were fed only the bite or two of food which they received at the end of each of the five runs. This procedure was used to minimize the number of retracings on the record day. The time spent in the Straightaway trials 15-20, on the seventh day, was the measure of speed which was recorded for the inter-correlations. The score used was the number of seconds elapsing between the complete entrance into the Straightaway and complete entrance into the food box. Records were not used for the first 12 animals because of errors in timing.

It became apparent after observation of the rats' behavior even on trials 15-20, with strong motivation, that the scores would not measure pure speed of motor reaction. Retravings were still made in many instances. In others, some of the rats were apparently afraid to go through the trap door at the end. Apparently, wildness and learning elements still entered into the rats' behavior.

Simple maze. This maze is the same as that used by Leeper (10) and was included in an effort to measure the rat's ability

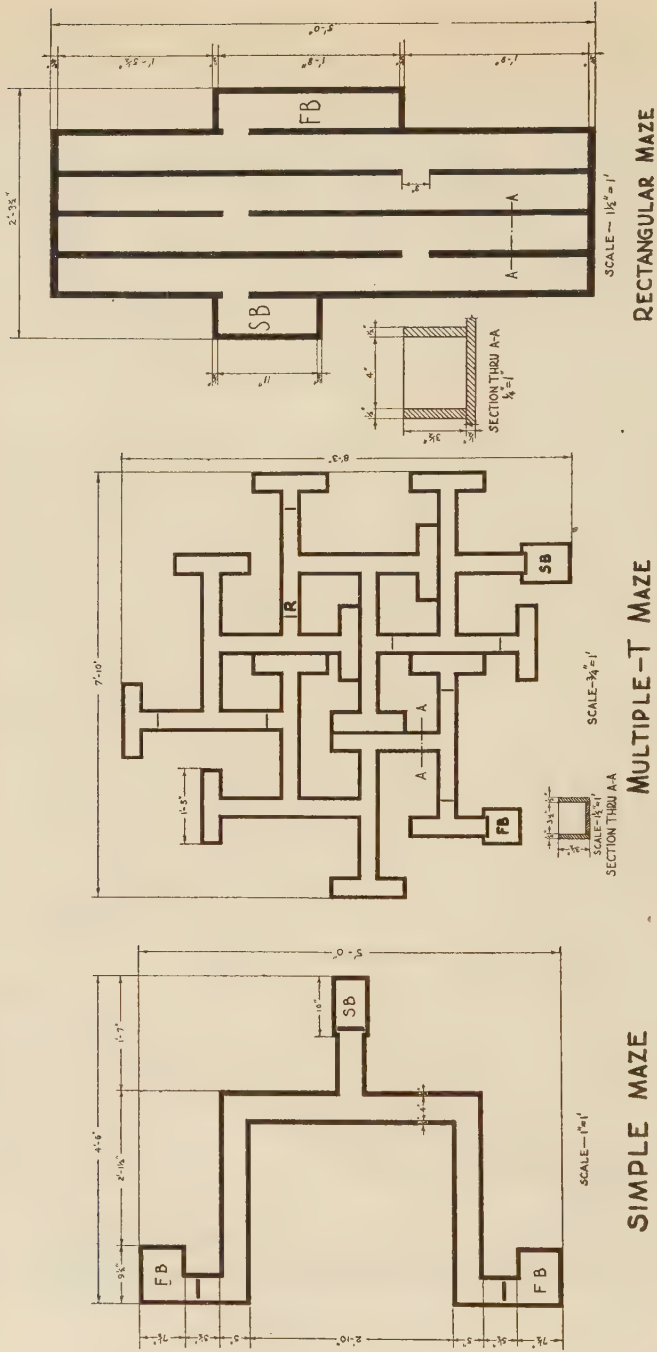


FIG. 2. DIAGRAMS OF APPARATUS

to make a simple association. Figure 2 shows the design. Upon being released from the starting box of the apparatus, the animals could go either right or left and proceed to the end without further choice. The rats were trained for three habits on this maze. On the first set-up, the right going response was correct; on the second, the left-going; and on the third they were trained to go back to the right—in all, two reversals plus the original right-going habit.

The animals began preliminary feeding in the right food box the day after they had finished with the Straightaway. They were fed 15 minutes on each of two days. On the third they were given one trial and allowed to eat for 15 minutes upon completing the run. On the fourth, they were given five trials and fed for ten minutes. Thereafter they were given ten trials a day until reaching the criterion of mastery. The criterion was ten consecutive errorless runs to the right. Animals not meeting the criterion in one hundred trials were discontinued on this problem and started on the next. Only seven minutes of supplementary feeding were given during the ten-trial-a-day training period. Four scores—total time in alleys, time in errors, number of errors, and trials to meet the criterion—were kept. Only entrances farther than the end of the elbow of the blind were recorded as errors, the time-in-error score being the number of seconds during which the rat stayed in the cul. Total time included this period plus the remaining time elapsing after the animal had left the starting box and completely entered the food box. Time records were discarded for the first 12 animals because the clock used was found to be in error.

The animals were given a three-day rest period after the poorest of the group had formed the right-going habit. They were then given five re-enforcing trials to the right. The left-going response was then made correct, five trials to the left immediately following those to the right. The animals were then given ten trials a day on the left-going habit until mastery. The criterion, as before, was ten consecutive errorless trials. Time in the maze, time in errors, errors, and trials were recorded, the same type of error and time measures being used as previously. The timing

method was the same as before, records from the first 12 animals being discarded.

Each animal was reversed to the right immediately after meeting the criterion for the left-going habit. The animals were reversed after one hundred trials if they had not met the left-going criterion before. Scores recorded and the criterion on the second right-going habit were the same as on the left-going and first right-going habits. The antagonistic habits were set up in an attempt to obtain some measure of the animals' reversal ability. Three days of rest were allowed after this task was completed by the slowest animal.

Multiple-T maze. The 12-cul-de-sac Multiple-T Maze was the seventh test in the series. The apparatus is shown in Figure 2. It is practically the same as that used by Stone and Nyswander (15), Tolman and Nyswander (19), Leeper (9), and others. It appears to be one of the most reliable tests of learning ability in the rat and was included as a test of that ability. Doors to prevent retracing were placed at the four points indicated in the drawing. False doors to obviate, somewhat, systematic visual cue were included.

The procedure was essentially the same as in the preceding tests, with three 15 minute preliminary feeding periods and one trial on the fourth day. The animals were given only five trials a day thereafter, however, and the criterion of mastery was only five consecutive errorless trials. Animals not reaching the criterion in 75 trials proceeded to the next task after another three-day rest period. Total time, time in error, error, and trial scores were recorded. Only entrances (two-thirds) into culs were counted as errors. Time spent in the culs was the time-in-error score. Total time included this plus the time in the correct pathway.

Rectangular maze. This apparatus is the same as Lashley's (6) Maze III and Lashley and Wiley's (8) Maze V. According to their results, error scores from it correlate highest of any variable studied with extent of cerebral lesion. Lashley (6) interprets it as a measure of intelligence of the rat. Figure 2 illustrates the design. The procedure was similar to that in the preceding tasks

—three days of preliminary feeding, 15 minutes a day, one trial on the fourth day, and ten trials a day thereafter until the animal had made either ten successive errorless runs or had taken a total of one hundred trials. Entrances into culs were recorded as errors, time spent in culs as time in errors, and time between complete exit from the starting box and two thirds' entrance into the food box as total time. The animals were given a seven-minute supplementary feeding period each day. The three-day rest period also followed this task.

Double platform problem box. Figure 3 gives a perspective of the problem box used. It is practically the same as Lashley's (6). To release the catch on the door leading to food, the animals had to push first on the right then on the left pedal. The release pedals required more than fifty and less than one hundred grams for operation. What the test measures is difficult to say, Lashley's (6, 7) results showing that it is not made more difficult by cerebral lesion as other latch boxes are. However, time scores give a plot in the nature of a learning curve.

Three days of preliminary feeding in the food compartment of this apparatus followed the rest period. On the fourth day the animals were given one trial. They were then given ten trials a day until mastery. The mastery criterion was five consecutive runs averaging five seconds or less per run, with none over eight seconds. Animals not reaching the criterion in 150 trials were discontinued on the problem. Supplementary feeding lasted for seven minutes. Total time and trial scores were recorded. Time, as before, was taken with the stop watch, and consisted of that elapsing between complete entrance into the reaction compartment and complete entrance into the food box. Three days of rest followed, as before.

Light discrimination box. Eighth in the series of tests was the Multiple-Light Discrimination Box. It is the same as that used by Krechevsky (5) and consisted of four units, in each of which the animal had to go through the light to reach the next. Figure 3 gives the design. The food reward was in a box at the end. The doors in the four sections could be operated with the lights to vary the order of correct runways and prevent solutions in

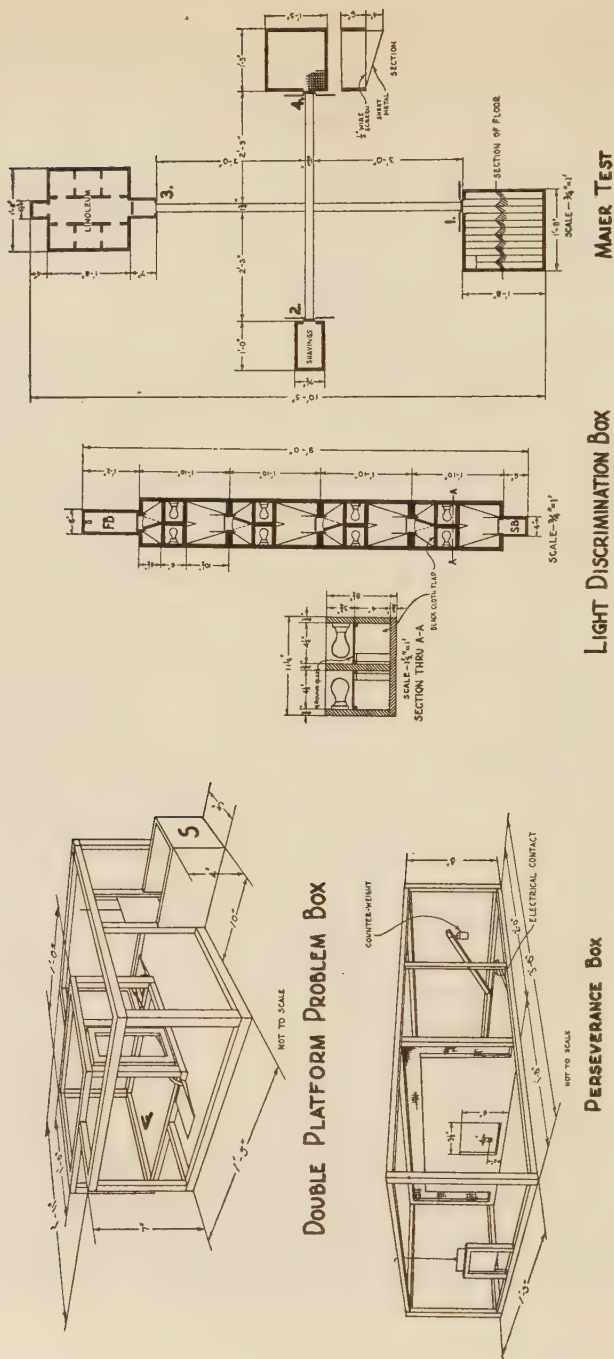


FIG. 3. DIAGRAMS OF APPARATUS

terms of spatial cues. The order of correct pathways was altered each trial. No shock was used. Performance scores in this box were thought to measure a visual capacity of the animal, and it was included to enable identification of such. With the normal animal many other factors obviously enter.

One trial followed the three days of preliminary feeding and ten trials a day thereafter until mastery. The criterion was four out of five errorless trials with only one error on the unsuccessful trial. Animals not reaching the criterion in 70 trials were started on the next test. Supplementary feeding was six minutes. Time, trial, and error scores were recorded. Time scores were those between complete exit from the starting box and complete entrance into the food box. Entrances into the dark alleys were considered errors.

Maier test. Immediately following completion of the light discrimination task, each animal was placed on the modified Maier (12) apparatus, supposedly a test of reasoning ability of the rat. The apparatus used consisted of four boxes, of different sizes and floor texture, connected with each other by narrow strips of wood. The floor of one box was covered with shavings, another with linoleum, another with one-half inch wire screen, and the fourth with corrugated wood. The tops of the boxes were covered with white cotton cloth and their fronts with tin. Figure 3 includes an illustration of the apparatus.

The rats were allowed a six-day exploratory period on the apparatus, one hour each day. They were then given three trials a day for 15 days. The animal was fed for one minute in the correct box, placed in another, and allowed to run until it had reached the correct one. It was permitted to feed there for one minute and then taken to the next for exploration and feeding. A definite order of correct boxes for the 45 trials was maintained. On each trial the animal was started from the box which was correct for the preceding one. In making up the order of correct boxes, the experimenter kept three items in mind: (1) no box was to be correct twice the same day; (2) the box not correct the preceding day (there were four boxes and only three trials a day) was to be correct the first trial on the following; and (3) the cor-

rect box for one trial was to be the starting box for the next. Error scores (entrances into wrong boxes) were kept for each trial.

Only the last 43 animals were given this test. This fact was due to the writer's failure on an apparatus similar to Honzik's (4) to secure more than chance results with small dispersion, for the first animals tested. Inasmuch as only the perseverance test followed this one, it was not thought that this change would affect the results. The number of test periods and the number of trials per day on the Honzik and Maier apparatus were the same.

Perseverance box. The so-called Perseverance, or Persistence, Box was merely a compartment divided into two sections by a partition with a doorway. Varying thicknesses of paper could be inserted in the doorway to obstruct the animal's passage from the release compartment into the food box. Directly in front of the food was a falling platform, which the animal had to step on before eating. The platform was attached to an electric clock which stopped when the pedal dropped. When the animal was released, the clock was started; when it reached food, the clock stopped automatically. Figure 3 gives the design of the apparatus.

The animals were fed for three days, fifteen minutes a day, in the box. They were then placed in the outer compartment and had to find their way to the food. On the fourth day a sheet of 16-pound wood pulp paper was inserted between the two sections and the animal placed in the release compartment. A small hole near the center of the paper facilitated the animal's attack. On the days following, five, 18, and 32 sheets of paper were inserted in the slot. Animals not tearing through the obstruction in two hours were returned to their home cages without food. On the following day the next test was given.

It was thought that this test would measure a persistence element of the rats' behavior. Observation of the animals, however, showed that the reaction to the first obstruction was more one of startle, or surprise; although after having gone through the partition once or twice, the animals attacked the obstruction quite vigorously upon first being placed in the reaction compart-

ment. Scores from this latter behavior (with 18 and 32 sheets) are what one might consider to be measures of persistence and those from the first type (on one and five sheets), measures of what Lashley (7) terms readiness with which the animals use force to meet an obstacle.

III. VARIABLES AND INTERCORRELATIONS

Measurements of different aspects of the rats' behavior in the twelve situations, combined with age, total percentage weight change before the beginning of each task and a second wildness measure, gave a set of 34 variables. In general four measurements were taken to represent the rat's performance in each situation. They were the number of entrances into culs-de-sac (errors) on a given number of trials, the number of trials to meet a criterion, the time spent in the correct pathway for a given number of trials, and the time per error for those trials. Product-moment correlations between these variables were computed.

Variables. The measures intercorrelated were as follows.

Variable 1: Age. The variables for each test were correlated with the animals' ages at the beginning of the task.

Variable 2: Percentage weight change. Total percentage weight change between the time that the animals were brought from the colony and the day they began each task was utilized for this variable. Since the incentive through the experiment was food, it was thought this measure would give a rough indication of different degrees of motivation. Stone (14) and others have used a similar measure to indicate varying degrees of hunger; however, under certain conditions (see variable 3) it was thought the weight change variable is predominantly a measure of other factors.

Variable 3: Wildness—percentage weight drop during the first three days after the animals were taken from the colony. The writer noticed that during these three days some of the rats refused to eat, and they urinated and defecated excessively. Stone (16), Yerkes (22), and others have used urination and defecation as criteria of wildness. Both refusal of food and excessive urination and defecation would tend to produce a weight drop, and the assumption made in terming this measure "wildness" is that the

wilder animals tend to lose the most weight. Obviously, other factors enter to produce the weight drop.

Variable 4: Wildness—time in the stovepipe tunnel.

Variable 5: Activity—number of revolutions on the activity wheels, days 9-14. That this variable does not measure all types of activity is obvious.

Variable 6: Time in Straightaway, trials 15-20.

Variable 7: Trials to master first right-going habit.

Variable 8: Number of errors, trials 2-12, first right-going habit.

Variable 9: Time per error, trials 2-12, first right-going habit. (Time in errors divided by number of errors.)

Variable 10: Time in the correct pathway, trials 2-12, first right-going habit. (Total time minus time spent in errors.)

Variable 11: Trials to master left-going habit.

Variable 12: Errors, left-going habit, trials 2-16.

Variable 13: Time per error, trials 2-16, left-going habit.

Variable 14: Time in correct pathway, trials 2-16, left-going habit.

Variable 15: Trials to meet criterion, second right-going habit.

Variable 16: Number of errors, trials 2-13, second right-going habit.

Variable 17: Time per error, trials 2-13, second right-going habit.

Variable 18: Time in correct pathway, trials 2-13, second right-going habit.

Variable 19: Trials to meet criterion, Multiple-T Maze.

Variable 20: Errors, trials 2-16, Multiple-T Maze.

Variable 21: Time per error, trials 2-16, Multiple-T Maze.

Variable 22: Time in correct pathway, trials 2-16, Multiple-T Maze.

Variable 23: Trials to meet criterion, Rectangular Maze.

Variable 24: Errors, trials 2-12, Rectangular Maze.

Variable 25: Time per error, trials 2-12, Rectangular Maze.

Variable 26: Time in correct pathway, trials 2-12, Rectangular Maze.

Variable 27: Trials to meet criterion, Double-Platform Problem Box.

Variable 28: Time, trials 2-26, Double-Platform Problem Box.

Variable 29: Trials to meet criterion, Multiple-Light Discrimination Box.

Variable 30: Errors, trials 1-11, Multiple-Light Discrimination Box.

Variable 31: Time, trials 1-11, Multiple-Light Discrimination Box. (Time in errors not excluded.)

Variable 32: Number of errors, 45 trials, Maier Test.¹

¹ Errors and errorless trials on this test correlated—.74.

Variable 33: Total time to gnaw through one plus five sheets, Perseverance Box.

Variable 34: Total time to gnaw through 18 plus 32 sheets, Perseverance Box.

Correlation method. Intercorrelations between these variables were computed by the product-moment formula. The scores were first grouped into ten class intervals on the basis of 75 cases and the intercorrelations computed between variables 1, 2, 3, 4, 5, 7, 8, 11, 12, 15, 16, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 33, and 34. Records for rat 20 were lost on the Rectangular Maze and were not obtained for rats 27, 58, and 80 on the Perseverance Test. To facilitate computation and inclusion of their records on the other tests, the median class interval scores for the group on these tasks, were listed for these animals. Intercorrelations with variables 6, 9, 10, 13, 14, 17, and 18 were based on 63 cases, and those with 32, on 43 cases. Regroupings for those 43 animals were made on the variables in which the number of class intervals represented was less than six. The cross product, squares, and sums were computed by the Tabulating Bureau of the University. The correlations were made to three places but rounded off to two for publication purposes.

Intercorrelations. Table II gives the intercorrelations between the 34 variables. In general they are low. About 30 per cent have an absolute value equal to or greater than .20. Only 22 of the 561 correlations are greater than .40. These small values are in accord with those ordinarily found in animal studies, as indicated by Thorndike's (17) review.

IV. FACTOR ANALYSIS

The problem set for this experiment required:

- (1) the factorial description of the variables in terms of a set of arbitrary reference vectors; and
- (2) the rotation of the reference axes towards the clusters of variables.

Thurstone's (18) centroid method with unknown diagonals was used to determine the arbitrary reference axes. An attempt to discover a simple order in the configuration was made with an

Intercorrelations

VARIABLE NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1															
2	*														
3	-.45	†													
4	-.02	-.21	+.21												
5	-.09	-.33	+.06	-.07											
6	-.13	+.06	-.03	+.10	-.13										
7	+.10	+.13	-.19	+.09	-.14	+.22									
8	+.17	+.02	-.33	+.02	+.08	+.17	+.29	*							
9	-.11	+.12	+.01	+.01	-.11	+.56	+.22	-.01							
10	-.06	+.02	+.12	+.05	-.05	+.38	+.28	+.44	+.27						
11	+.18	+.21	-.23	-.07	+.01	+.08	+.34	+.20	+.13	+.23					
12	+.07	+.16	+.17	+.19	-.01	-.07	+.12	+.06	+.01	+.10	+.05				
13	+.09	+.22	-.09	+.08	-.22	+.31	+.14	-.09	+.53	+.30	+.19	+.06			
14	-.14	+.25	+.15	+.29	-.13	+.27	+.10	+.05	+.11	+.53	+.11	+.32	+.33		
15	+.25	+.36	-.05	-.02	+.05	-.07	+.32	+.28	+.01	+.15	+.20	+.31	+.01	+.00	
16	+.14	+.15	+.01	-.25	+.10	-.10	+.15	+.10	-.18	-.16	+.07	+.10	-.27	-.10	+.20
17	-.20	+.09	+.08	-.05	-.25	+.02	-.11	-.31	+.06	-.01	-.14	+.07	+.31	+.27	-.20
18	-.10	-.19	+.10	-.07	+.17	+.05	-.18	-.01	-.09	-.15	-.06	-.23	+.01	-.11	-.19
19	+.27	+.10	-.08	-.01	-.16	+.18	+.10	+.08	+.18	-.08	+.25	+.20	+.12	+.10	+.12
20	+.07	+.02	-.09	-.11	-.20	+.18	+.00	+.11	-.05	-.16	+.13	+.05	-.05	+.02	+.09
21	+.00	+.11	+.01	-.08	-.04	+.46	+.05	+.14	+.33	+.33	+.21	+.20	+.31	+.33	+.03
22	+.22	+.12	-.20	-.13	-.12	+.47	+.10	+.15	+.19	+.18	+.20	+.01	+.28	+.27	-.01
23	+.28	+.25	-.18	-.13	-.04	+.21	+.43	+.26	+.19	+.14	+.44	+.28	+.19	-.04	+.29
24	+.34	+.24	-.09	-.09	+.12	-.01	+.23	+.24	-.05	+.07	+.30	+.16	+.02	-.01	+.15
25	+.27	+.19	-.01	+.09	+.17	+.04	+.00	+.01	-.04	+.05	+.13	+.04	+.21	+.13	-.04
26	+.33	+.17	-.04	+.04	-.00	+.15	+.10	+.04	+.03	+.04	+.20	+.15	+.18	+.15	-.02
27	-.04	+.19	-.14	-.12	-.04	+.22	+.11	+.06	+.08	+.25	+.17	+.29	+.22	+.28	+.27
28	+.24	+.07	-.10	-.20	-.15	+.32	+.03	+.12	+.22	+.02	+.19	+.20	+.17	+.03	+.06
29	+.24	+.10	-.24	-.06	-.06	+.11	+.18	+.23	+.06	+.13	+.28	+.16	+.19	+.05	+.12
30	+.10	+.11	-.19	+.02	+.01	+.15	+.14	+.15	+.16	+.15	+.27	+.08	+.31	+.08	+.07
31	-.06	+.15	-.10	-.08	-.07	+.37	+.09	+.03	+.20	+.14	+.28	+.06	+.32	+.08	+.09
32	-.03	+.23	-.02	+.04	+.18	+.07	+.32	+.25	+.02	+.17	+.03	-.27	-.27	+.15	+.05
33	-.06	+.00	+.13	-.14	+.18	-.03	+.06	+.05	-.14	-.09	-.05	+.10	-.18	-.13	-.10
34	-.16	+.17	-.24	+.02	-.08	+.04	-.02	+.24	+.11	+.09	-.03	-.16	+.21	-.01	+.05

* Correlations between 1 and 2 were different for each task. All but two were less than .20, and

† This correlation is in a sense a reliability coefficient, and the highest correlation of the two v

LE II

between variables

17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
+ .16																	
+ .24	- .14																
- .02	- .13	+ .58															
+ .10	+ .07	+ .26	+ .50														
+ .07	+ .05	+ .36	+ .74	+ .76													
- .05	- .03	+ .22	+ .21	+ .26	+ .26												
+ .04	+ .07	+ .22	+ .25	+ .13	+ .19	+ .28											
+ .30	- .05	+ .04	+ .06	+ .23	+ .20	+ .15	+ .53										
+ .24	- .03	+ .11	+ .21	+ .22	+ .23	+ .18	+ .74	+ .74									
+ .07	+ .06	+ .13	+ .21	+ .40	+ .32	+ .35	- .01	+ .10	+ .06								
+ .10	- .10	+ .28	+ .38	+ .41	+ .46	+ .27	+ .19	+ .20	+ .37	+ .32							
- .12	+ .07	+ .18	+ .15	+ .05	+ .18	+ .38	+ .15	- .02	+ .03	+ .36	+ .15						
+ .05	+ .06	+ .28	+ .24	+ .24	+ .33	+ .34	+ .10	+ .15	+ .02	+ .22	+ .23	+ .38					
+ .25	- .01	+ .32	+ .14	+ .27	+ .25	+ .23	+ .09	+ .23	+ .16	+ .25	+ .41	+ .11	+ .68				
- .01	+ .17	- .11	- .14	- .13	- .05	+ .00	+ .31	- .02	- .01	- .09	+ .08	+ .04	- .05	+ .00			
- .24	+ .05	- .17	- .14	- .10	- .13	- .05	+ .11	- .09	- .02	- .11	+ .12	- .03	- .25	- .11	+ .35		
- .08	- .02	+ .07	+ .18	+ .15	+ .18	+ .04	- .12	- .13	- .04	+ .10	+ .25	+ .11	+ .07	- .04	+ .04	- .03	

unpublished graphical method devised by Thurstone for configurations in more than three dimensions. Only orthogonal rotations were made. Although there is a possibility that oblique rotations would give results more adequately satisfying the criteria for a simple structure, it was thought that the factors obtained by the orthogonal rotations would closely approximate those which would be obtained by the oblique transformations. It might be stated that the axes have remained practically orthogonal in several studies in which oblique transformations have been made.

Centroid Analysis

Centroid matrix. A matrix with eight columns, or factors, was obtained by the centroid method. Table III is this matrix with the communalities. The centroid analysis was continued until the greatest contribution that any loading could make to the communalities was equal to or less than .10. Two exceptions were permitted (on variables 6 and 32), as the loadings were but .36; and their contributions to the communalities were but .13. Two more factors were added after this analysis had been made, to insure that sufficient degrees of freedom were allowed for the rotations.

Residuals. Figure 4 is the distribution of the eighth factor residual coefficients. About 87 per cent of them are equal to or smaller than .10. None is greater than .30.

Communalities. The communalities of the variables are in general low. The median is about .49.² Five variables have communalities greater than .70. They are numbers 20, 22, 24, 25, and 26. The variance in scores on these tests is pretty well accounted for by factors common to several variables. Seven variables—numbers 4, 5, 12, 16, 20, 33, and 34—have communalities lower than .30. This fact indicates that these variables measure little in common with others of the battery.

² The reliability of the tests would be higher, as the communality does not include that part of the variance in scores which is specific to a particular test.

TABLE III
Centroid matrix and communalities*

	I	II	III	IV	V	VI	VII	VIII	h ² †
1	+.27	-.43	+.36	+.16	-.22	-.13	-.09	+.20	.53
2	+.33	+.24	+.18	-.08	-.13	-.32	+.17	-.37	.50
3	-.22	+.32	-.09	-.32	-.31	-.23	+.24	-.36	.59
4	+.02	+.20	-.05	-.17	+.14	-.28	+.19	+.26	.27
5	-.23	-.11	+.19	-.11	-.15	+.30	-.15	-.05	.24
6	+.47	+.24	-.28	-.06	-.07	+.36	+.10	+.21	.56
7	+.40	+.21	+.41	+.05	-.21	+.15	+.18	+.04	.48
8	+.33	+.08	+.39	+.20	+.09	+.24	+.16	+.24	.45
9	+.36	+.30	-.22	-.12	+.19	+.16	-.07	+.10	.38
10	+.42	+.48	+.12	-.16	-.07	+.18	+.14	+.30	.60
11	+.45	-.10	+.26	-.00	+.18	+.19	+.01	-.09	.36
12	+.26	+.12	+.13	+.19	+.03	-.30	-.07	-.25	.29
13	+.51	+.23	-.27	-.24	+.26	-.09	-.29	+.09	.61
14	+.39	+.44	-.11	-.26	-.26	-.15	+.15	+.04	.53
15	+.28	+.08	+.39	+.24	-.08	-.13	+.16	-.15	.37
16	-.06	-.19	+.37	+.12	+.22	+.09	+.33	-.25	.42
17	+.15	-.02	-.36	-.31	-.11	-.25	-.08	-.15	.35
18	-.12	+.05	-.15	-.15	-.14	+.24	-.20	-.15	.20
19	+.48	-.28	-.20	+.19	-.06	-.16	+.18	-.22	.49
20	+.43	-.41	-.31	+.46	+.29	-.10	+.27	-.05	.83
21	+.60	+.03	-.34	+.11	+.38	+.15	-.10	+.11	.68
22	+.63	-.21	-.34	+.24	+.35	+.17	+.07	+.19	.81
23	+.56	+.03	+.28	+.18	-.17	+.11	-.22	-.22	.57
24	+.41	-.37	+.51	-.30	-.32	-.06	-.08	-.12	.78
25	+.38	-.37	+.13	-.34	-.23	-.18	-.21	+.09	.73
26	+.47	-.38	+.19	-.43	-.33	-.27	-.30	+.14	.87
27	+.45	+.18	+.03	+.21	+.10	+.08	-.18	-.22	.38
28	+.53	-.16	-.13	+.19	+.24	+.09	-.23	-.10	.48
29	+.38	+.02	+.14	+.19	-.15	+.15	-.12	-.18	.29
30	+.52	-.16	-.17	-.10	+.31	+.29	+.12	-.27	.59
31	+.50	-.16	-.26	-.26	+.17	+.31	+.12	-.35	.68
32	-.00	+.13	+.34	-.15	-.29	+.36	+.25	-.09	.44
33	-.21	+.05	+.28	+.08	+.31	+.21	-.11	-.11	.29
34	+.21	+.19	-.16	+.19	+.04	-.04	-.10	+.08	.17

* Computations were carried out to three places but numbers rounded off to two for publication.

† Communalities.

Rotation of axes

The centroid matrix was simplified by rotating the reference axes in orthogonal planes to maximize the number of zero entries in the table. This procedure not only increases the number of zeros; but it also increases the projections of some of the points

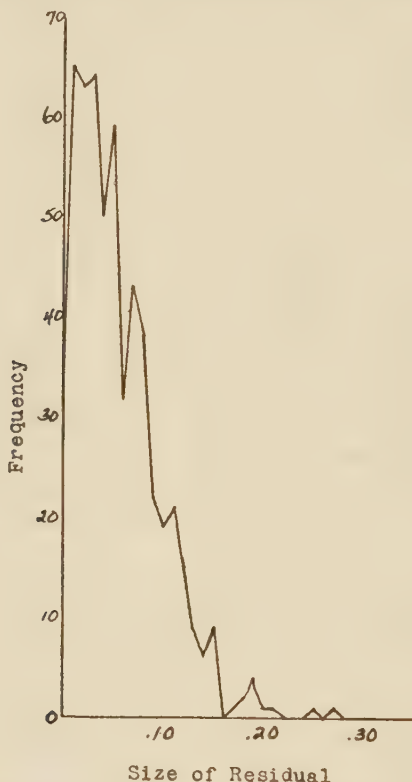


FIG. 4. DISTRIBUTION OF EIGHTH FACTOR RESIDUAL COEFFICIENTS

on the reference axes. It reduces the matrix to its simplest possible order with orthogonal reference axes.

Method. Plots of each factor with every other one were made. For instance, the entries in column I of the centroid matrix were plotted against the entries in II, against those in III, in IV, and so on, successively. Those in II were also plotted against III, IV, V, VI, and so on. Likewise columns III, IV, and V were plotted

against the remaining ones. Twenty-eight such graphs were thus obtained. Figures 5, 6, 7, 8, 9, and 10, represent the type

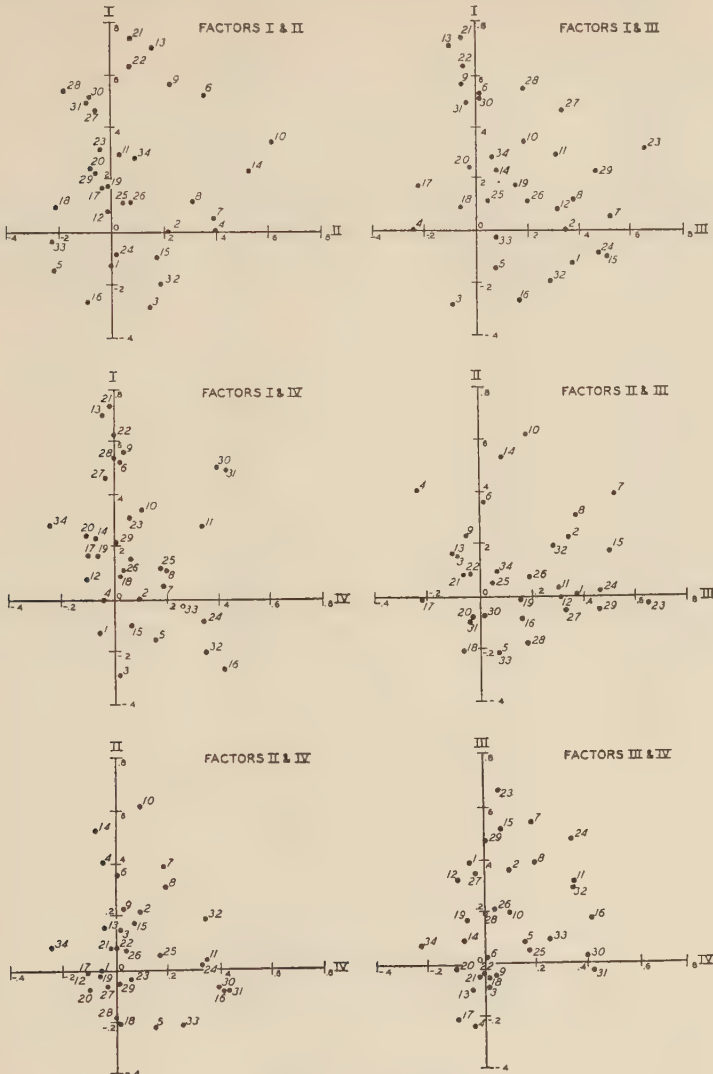


FIG. 5. FACTOR PLOTS

of graph made; however, they are plots of the final factorial matrix.

By inspection, new orthogonal axes were drawn through clusters of points in such a manner that the projections of the points

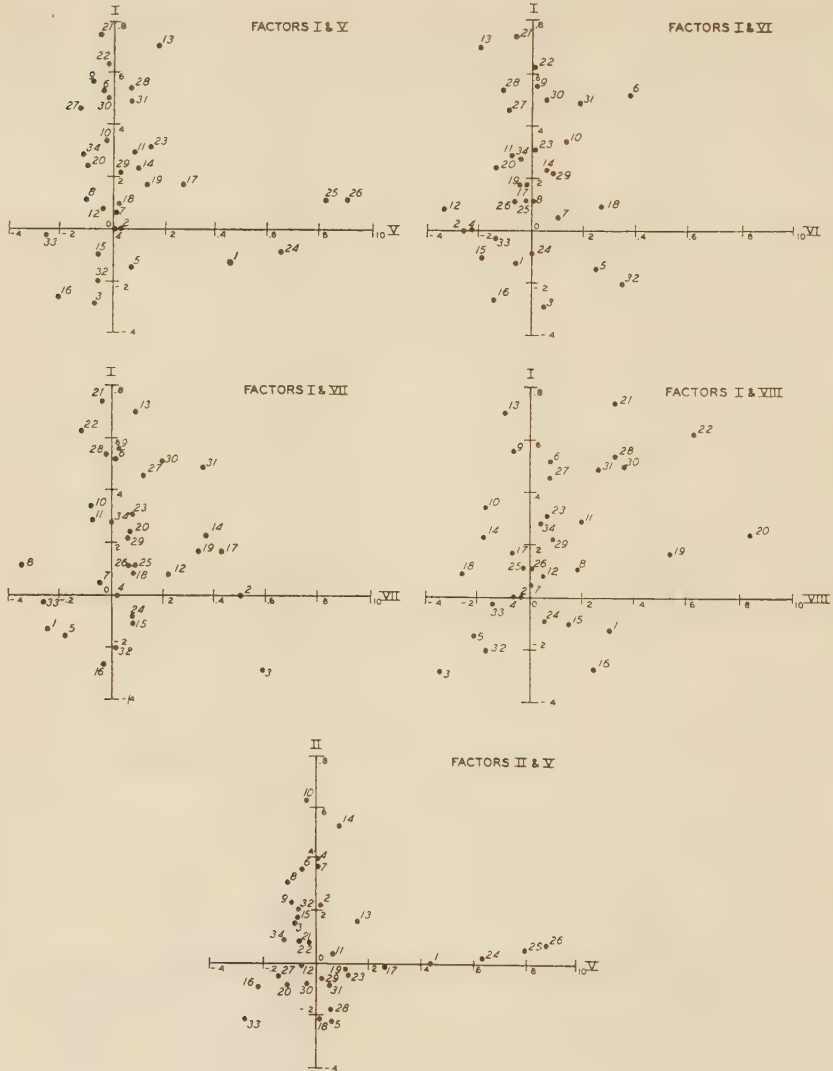


FIG. 6. FACTOR PLOTS

upon these axes would in the greatest number of instances be zero.³ that is, the axes were passed through clusters of the

³ Loadings between $\pm .10$ were considered zero within experimental error.

variables. A transformation matrix by which the centroid matrix was to be multiplied was then set up. The transformation



FIG. 7. FACTOR PLOTS

matrix was one which, by the multiplication, would rotate the reference axes to the positions desired, as indicated by inspection

of the graphs. The sine and cosine of the angles of rotation, entered in the transformation matrix, were taken from the graphs.

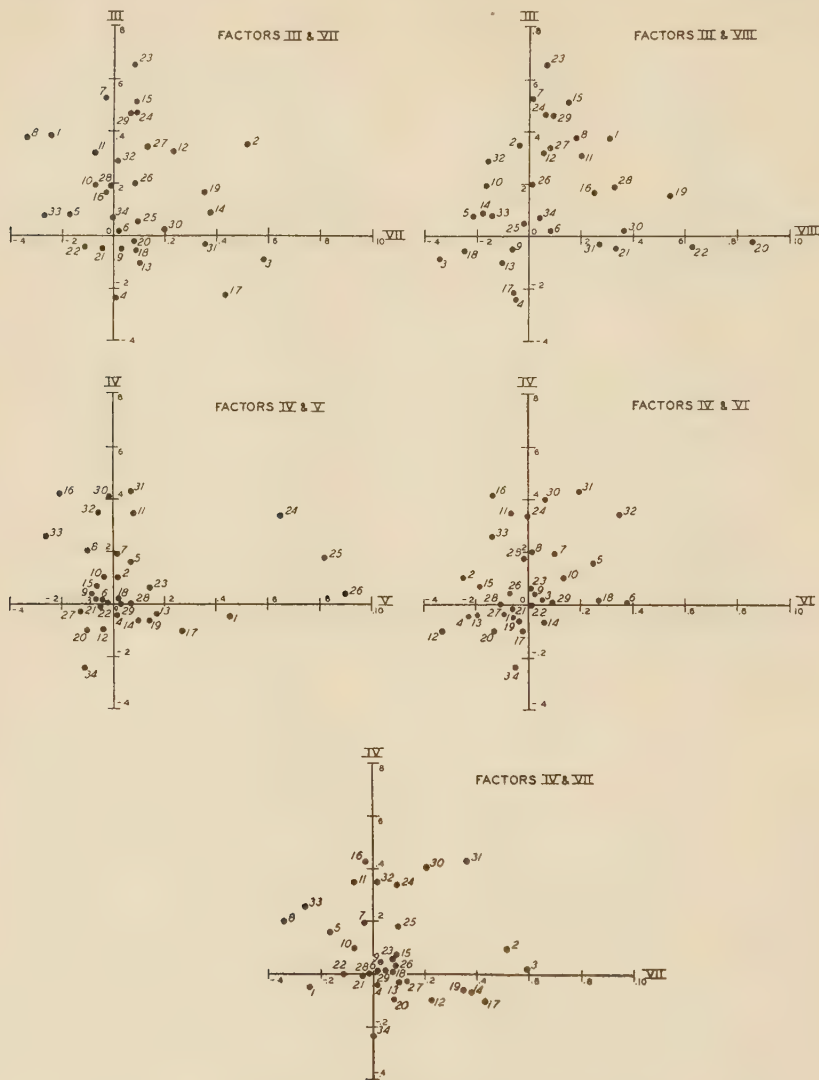


FIG. 8. FACTOR PLOTS

The procedure was repeated for the factorial matrix obtained by the first rotation. That is, graphs were made, a second trans-

formation matrix set up, and a third matrix obtained. In all, 13 such rotations were made. Table IV is the composite or-

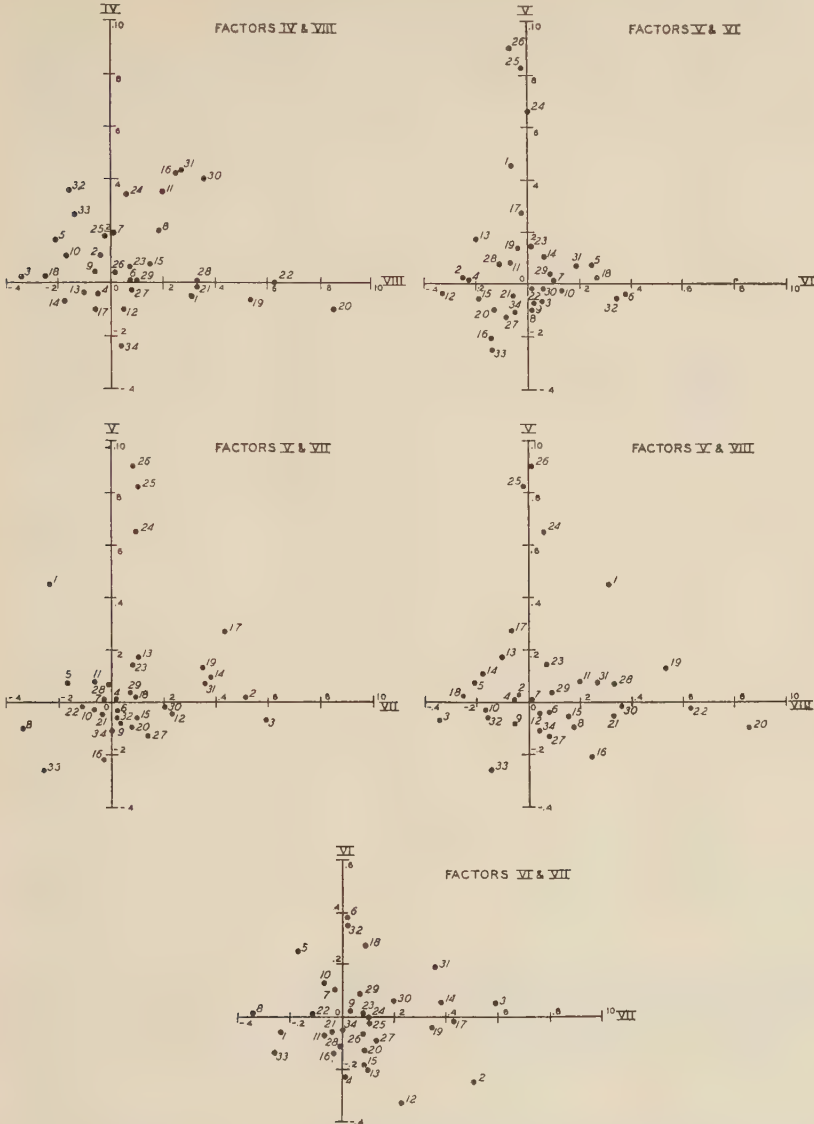


FIG. 9. FACTOR PLOTS

thogonal transformation matrix. The centroid matrix multiplied by this one reproduces the factorial matrix.

Factorial matrix. Table V is the final factorial matrix. Figures 5, 6, 7, 8, 9, and 10 are plots of this matrix. The plot of I against II, for instance, indicates that Factor I is markedly manifest in Variables 21, 13, and 22, and Factor II is absent. Likewise the plot of I against III shows variables 21 and 22 to be highly loaded with I but not with III, and so on. The factor

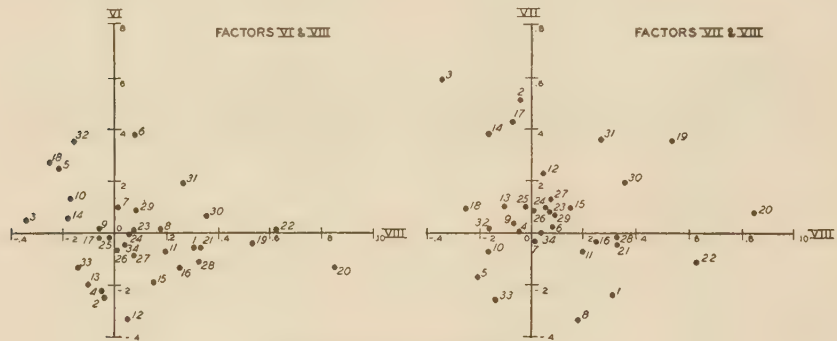


FIG. 10. FACTOR PLOTS

TABLE IV
Transformation matrix

	1	2	3	4	5	6	7	8
1	+.66	+.32	+.43	+.10	+.30	-.06	+.20	+.37
2	+.23	+.47	+.13	-.16	-.52	-.08	+.15	-.61
3	-.38	+.11	+.62	+.44	+.11	-.30	-.36	-.19
4	-.07	-.18	+.42	-.52	-.51	-.05	-.23	+.45
5	+.35	-.14	-.36	+.38	-.36	-.59	-.28	+.16
6	+.27	-.17	+.10	+.41	-.28	+.72	-.33	-.05
7	-.40	+.54	-.15	+.33	+.32	+.14	+.26	+.47
8	+.03	+.53	-.27	-.29	+.24	+.08	-.70	+.05

plots also show that only very slight rotations which will gain zeros can be made by this method, with the exception of the plots of I against VIII and II against VI. These axes may be rotated somewhat, but the interpretation of the loadings as they are is better than they would be with the change. The rotations were made, however, to discover whether they would provide for further transformations on other axes, but they do not.

TABLE V
Factorial matrix*

	I	II	III	IV	V	VI	VII	VIII
1	-.13	.00	+.38	-.05	+.45	-.06	-.24	+.31
2	.00	+.22	+.35	+.10	+.02	-.25	+.51	-.04
3	-.29	+.15	-.09	+.02	-.07	+.05	+.59	-.34
4	.00	+.40	-.24	-.04	+.01	-.23	+.01	-.05
5	-.15	-.22	+.08	+.16	+.07	+.25	-.17	-.21
6	+.52	+.36	+.02	+.01	-.04	+.38	+.02	+.08
7	+.05	+.39	+.53	+.19	+.01	+.10	-.03	+.01
8	+.11	+.31	+.38	+.20	-.10	+.01	-.34	+.18
9	+.56	+.23	-.05	+.04	-.08	+.02	+.03	-.06
10	+.34	+.62	+.19	+.10	-.03	+.13	-.07	-.17
11	+.29	+.03	+.31	+.35	+.08	-.07	-.07	+.20
12	+.08	-.01	+.32	-.10	-.04	-.33	+.23	+.05
13	+.70	+.16	-.10	-.04	+.17	-.20	+.10	-.10
14	+.23	+.53	+.09	-.07	+.10	+.06	+.38	-.18
15	-.10	+.17	+.51	+.07	-.06	-.19	+.09	+.15
16	-.27	-.09	+.17	+.42	-.21	-.14	-.03	+.25
17	+.17	-.01	-.22	-.10	+.27	-.02	+.43	-.06
18	+.09	-.21	-.06	+.02	+.02	+.27	+.09	-.25
19	+.17	-.02	+.16	+.06	+.13	-.04	+.35	+.54
20	+.24	-.08	-.02	-.10	-.10	-.13	+.08	+.85
21	+.74	+.08	-.05	-.01	-.05	-.06	-.04	+.33
22	+.63	+.08	-.04	.00	-.02	+.01	-.11	+.63
23	+.31	-.04	+.66	+.06	+.14	+.01	+.08	+.07
24	-.09	+.02	+.47	+.34	+.65	.00	+.09	+.06
25	+.11	+.05	+.05	+.18	+.82	-.02	+.10	-.02
26	+.11	+.07	+.20	+.04	+.90	-.07	+.08	+.01
27	+.46	-.06	+.34	-.03	-.13	-.09	+.13	+.08
28	+.54	-.18	+.19	.00	+.07	-.11	-.01	+.33
29	+.22	-.06	+.47	+.01	+.03	+.09	+.07	+.09
30	+.50	-.08	+.02	+.40	-.02	+.06	+.20	+.36
31	+.49	-.09	-.03	+.43	+.07	+.19	+.36	+.27
32	-.20	+.19	+.29	+.35	-.06	+.35	+.02	-.16
33	-.03	-.22	+.08	+.26	-.26	-.14	-.26	-.14
34	+.28	+.09	+.07	-.24	-.11	-.05	.00	+.04

* The term "factorial matrix" ordinarily denotes any matrix which when multiplied by its transpose reproduces the correlational matrix. It is used herein to designate that matrix which best satisfies the definition of simple structure by the method used.

V. DISCUSSION

The problem set for investigation requires the answer to two questions:

(1) To what extent are the various factors involved in the variables selected for study? and

(2) What do the factors mean psychologically?

The loadings given in Table V answer the first question. The second question requires an interpretation of the factors. The diagrams in Figure 5, that is, the plots of the first four factors, indicate that the variables lie in fairly definite clusters about the I, II, III, and IV axes; and the loadings with those factors show fairly definite trends in terms of psychological categories; how-

TABLE VI
Expected and actual weightings of variables if I is general speed factor

VARIABLES WITH EXPECTED LOW WEIGHTINGS	ACTUAL WEIGHTINGS	VARIABLES WITH EXPECTED HIGH WEIGHTINGS	ACTUAL WEIGHTINGS
7	+.05	6	+.52
8	+.11	9	+.56
11	+.29	10	+.34
12	+.08	13	+.70
15	-.10	14	+.23
16	-.27	17	+.17
19	+.17	18	+.09
20	+.24	21	+.74
23	+.31	22	+.63
24	-.09	25	+.11
29	+.22	26	+.11
30	+.50	27	+.46
32	-.20	28	+.54
		31	+.49
		33	-.03
		34	+.28

ever, some of the loadings seem to be non-meaningful. This fact may be due to chance elements, to inadequate rotational methods, or to inadequacy of the interpretations, which seem to be most plausible. Until further work has been done with a larger number of tests in each category, however, it seems advisable to consider the apparent exceptions as due to chance.

Identification of factors

Factor I is clearly a speed factor of some sort. The high loadings from as diverse measures as time scores on the Multiple-T

Maze and Double Platform Problem Box would indicate that the factor is quite general to motor tasks. It is perhaps the trait that Davis and Tolman (1) have distinguished as "slap-dash vs. deliberate." Assuming that such a factor is general to all motor tasks, one would expect high and low loadings as designated in Table VI. The actual loadings are given beside the numbers of the variables. Loadings of .30 or less might be termed insignificant.

There are but two variables which should have low weightings but which have loadings above .30, viz., Variables 23 and 30. The loading of Variable 30 is .50 but may be attributed to the close relationship between total time (time in errors not partialled out on this test) and number of errors. The addition of another factor would probably remove this loading, but the additional factor would be defined by only two variables. The loading of Variable 23 is but .51. Hence, variables other than time scores do not seem to measure the factor.

Of the 16 variables which should have high loadings according to this interpretation, seven have weightings below .30. They are Variables 14, 17, 18, 25, 26, 33, and 34. Variables 25 and 26 (from the Rectangular Maze) were apparently affected by some highly specific factor introduced at the time of this test, as they are loaded unusually high with Factor V. Other exceptions may have somewhat similar explanations. The results are quite suggestive, and the factor is one which should be explored further.

Factor II is a wildness-timidity trait. Arguments sustaining this interpretation are: (1) time in the Wildness Tunnel (Variable 4) has a relatively high loading; (2) tests in the earlier part of the series have high loadings, and those in the latter part have zero loadings; and (3) variables which would be most affected by hesitancy in entering trap doors (time in the correct pathway) during the earlier part of the training series have the highest loadings. Loadings as small as .25 are meaningful. Smaller ones may have some significance.

Factor III is interesting. Trial scores on the simpler tasks are consistently heavily loaded. Error scores on these tasks are weighted in the same direction but in general less highly. The loadings of time scores are negligible. Variables 1 and 2 (age

and percentage weight change) are loaded above .30 with III, but they are rough measures of the number of trials taken to master a previous task. That is, a group of animals that took a relatively large number of trials to master one task would in turn be slightly older and would gain slightly more weight than another group that took fewer trials. One would be tempted to term the factor a motivational one were it not for this fact, or if percentage weight change were loaded highly but not age. It may be, however, that the loading of the age variable has an explanation similar to that of Variable 30 with Factor I. If so, the factor might be termed "motivation," but then it is difficult to explain the low loadings of the time variables: supposedly differences in motivation would be reflected in time scores as much as in error or trial scores.

It is more than likely that the factor is some sort of memory or learning ability. The Maier test might be considered a measure of immediate memory, and it has a fairly high loading. Assuming that learning involves the repetition of correct responses more than the elimination of errors, the higher loadings of the trial variables would be explained. This interpretation—that is, of associative learning—seems most probable. On the other hand, it is difficult to explain the low loadings of the variables from the Multiple-T Maze. However, this task may involve a higher intellectual ability. It might be pointed out that the tasks which define III are probably simple enough for the rat that they can be learned in terms of insight into the situation. A simple principle—different in each—runs through all of the tasks. In one instance, the principle is a right-going one, in another a left-going one, in another a right-left alternation, and so on. There is some evidence from Thorndike's (17) factor plots (of I against III) that mazes involving only a simple principle are more closely related than those which involve a more complex one.

Factor IV, although defined by a fairly definite cluster, is not clear cut psychologically. The axis is defined by the error and total time variables from the Multiple-Light-Discrimination Box, the error variable from the second reversal habit, the trial variable from the first reversal habit, errors on the Rectangular

Maze, errors from the modified Maier test, and time to reach food in the first obstruction test. It seems likely that the loadings are due to a transfer effect: the reversal habits are on the apparatus which was used to set up the original right-going response, and the other tests with relatively high loadings were late in the training series. Considering the high loadings of the variables from the light discrimination apparatus, one might be led to believe that the factor is a visual one. However, some unpublished extirpation work with the Multiple-T Maze used in the experiments indicate that a visual element was involved in its mastery, but it has no loading with IV.

Factors V, VI, VII, and VIII seemingly cannot be identified. Factor V is quite conspicuous, but the loadings are restricted to variables from the Rectangular Maze. Factor VIII is similarly defined by variables from the Multiple-T Maze. Other than indicating the adequacy of the factor methods used (one would expect highly specific factors for some of the apparatus), the loadings show little.

Factors involved in tests

Although the entries in Table V roughly indicate to what extent the various tests measure these factors, it seems desirable to summarize the findings in terms of the interpretations tentatively suggested. It must be borne in mind, however, that the loadings may be markedly influenced by the conditions of the experiments and by the population used. The general applicability of the conclusions should be tested in other situations.

Wildness tunnel. The time variable from this test seems to differentiate animals from a fairly tame stock on the basis of a wildness-timidity trait. The variable has small negative loadings with an associative or insight learning factor and with another factor which cannot be identified in this battery. The latter two loadings are probably insignificant. The communality of the variable in this battery is small. As used, it is probably not very reliable.

Activity cage. The type of activity measured in this apparatus has little relationship to that involved in other tests of the bat-

tery. That is, the communality of the variable is small. The variable has slight positive or negative loadings with all but Factors III and V. The diverse loadings may indicate that the activity variable measures a complex of factors, although some loadings are probably due to chance.

Straightaway. The time variable from the Straightaway measures a speed factor general to several tasks. In this battery it also measures the wildness-timidity trait and another not identified.

Simple maze. Three habits were set up on this maze: The original right-going one, a left-going habit, and a second right-going habit. The latter two are reversal habits. Trial, error, time per error, and time in the correct pathway are variables which were used in these experiments.

Trial variables on all three tasks involve an associative or insight learning factor. Error variables likewise measure this factor, with the exception of that on the second right-going habit. In addition, trial and error variables on the first right-going habit involve the wildness-timidity trait. One would not expect the latter trait to be involved in the test were the animals thoroughly tamed. They had been handled for a long period, however, before this task. The trial variable on the first reversal habit and the error variable on the second reversal habit involve a transfer factor.

Time scores on the first right-going and the left-going habits involve a speed factor. The wildness-timidity trait was markedly manifest in the time-in-correct-pathway variables of these two tasks. This latter fact is probably due to retracings in the correct pathway after the animal had reached the door at the end.

Multiple-T maze. The trial and error variables are specific to the apparatus in this battery. Time per error in the first few trials seems to be an excellent measure of the speed factor isolated. Besides its loading with I, the latter variable has a slight weighting with the factor specific to the apparatus. Time in the correct pathway measures the speed factor and the specific factor.

Rectangular maze. Trial and error scores from this maze, and

especially the former, measure the associative or insight learning factor. Errors also measure the factor which, in this battery, is highly specific to the apparatus. The trial variable is loaded .31 with the speed factor, probably fortuitously. The two time variables measure only the factor specific to the apparatus.

Double platform problem box. The two variables, trials and time, from this task measure the speed factor. The loading of trials with I is undoubtedly due to the fact that the criterion of mastery is a function of the time taken to operate the latches on successive occasions. The trial variable also measures the associative or insight learning factor, and the time variable has a loading of .33 with Factor VIII.

Light discrimination box. The trial variable measures the associative or insight learning factor. Three factors seem to be involved in the error variable: the speed factor, the transfer factor, and VIII. The loading of the error variable with the speed factor is probably spurious. The time variable largely measures the speed and the transfer factors. The time variable also has a fairly large loading, .36, with Factor VII.

Modified Maier test. The error variable from this test has loadings greater than .15 with six of the eight factors. It thus seems to be a measure of a complex of factors, although some of the diverse loadings are probably due to chance. It has a relatively high loading with the transfer factor, and one equally large with VI. It has weighting of .29 with the associative or insight learning factor.

Obstruction box. The communalities of the variables from this apparatus are small. As used, the solution of the problem seems to be largely a matter of chance.

Summarizing, one finds only five variables which measure but one readily-identifiable factor, and their communalities are not extremely high. They are: (1) time in the Wildness Tunnel, which seems to measure the wildness-timidity trait; (2) time per error on the first right-going habit, which seems to measure the speed factor; (3) trials on the second right-going habit, which measure the associative or insight learning factor; (4) time per error on the Multiple-T Maze, which measures the speed factor;

and (5) trials to master the Rectangular* Maze, which seem to measure the associative or insight learning factor. Three other variables are loaded with but one factor, but the factors with which they are loaded are not identifiable in this battery. Two or more factors seem to be involved in all other tests, or the communalities are so low that the tests may be considered unreliable.

Modifications of tests for further study

The results from this study point to the need for developing reliable tests of unitary variables. For further factor analysis work it is also necessary that several tests in each category be developed. It is quite probable that slight modifications of tests used in this battery will greatly increase their value.

Although the time variable on the Wildness Tunnel is a fair test of one of the factors isolated, the measure would be improved by less preliminary feeding in the food box. Three or four trials, instead of one, would probably increase its reliability. The scoring might be improved by recording the time spent in the Tunnel after the animal reaches the exit. In so doing, one would obtain even a better measure of its hesitancy in leaving the darkened "shelter." Another measure of this same trait would be the number of retracings after the animal had reached the exit. A short straightaway with buzzer and trap door at the end might also be used. Two scores would be obtained from this task; time to enter the food box and number of retracings after reaching the trap door. Several trials on this latter apparatus should give a fairly reliable measure of the wildness-timidity trait.

Tryon's (21) eight principles of measurement important for animal work need not be reviewed. However, preliminary training to depress the wildness trait should extend over a long period, as this trait seems to persist for some time. One might use norms from wildness-timidity tests as a basis for deciding when the animals are sufficiently test-broken to begin training on the "learning" tests. Increasing the length of tasks, as Tryon (21) points out, would also tend to increase their reliability, although it is quite possible that by lengthening tests used in the learning

situation, one at the same time changes the essential nature of the tasks.

From the loadings with III in the present experiment, one would expect tasks involving only a simple principle to be closely related. A better control of motivation than is possible over a long training period would be advisable in determining definitely whether the factor is primarily a learning one. The addition of more similar elements to the rectangular maze, the light discrimination box, and other tests of this nature should increase their reliability. Similar tests in other sensory spheres should be correlated with ones in this battery to determine whether the trait is central. The type of learning measured may involve the repetition of correct responses more than the correction of errors, and it is possible that the scoring of such tasks in terms of the number of correct responses at the choice points would give a better measure of the ability.

Interestingly, the activity variable has but small loadings with the various factors, yet a certain amount of activity is involved in all tests. It may be that the period in the cages was too long, and samplings over a shorter period of time would give results which correlate higher with performance on mazes and other apparatus. Several activity tests should be included in further work to insure isolation of an activity trait. Persistence might be measured better by modifying the procedure with the paper obstruction box. The ratio of the amount of time spent in working at the obstruction to the amount of time in other activities during a two-hour period (after the response has been learned) might be considered such a measure. The animal should be given ten or fifteen trials first with only a few sheets of obstruction. Then the obstruction should be increased to 50 or 60 sheets.

Summary and conclusions

Intercorrelations between a set of 34 variables, derived from twelve tests commonly used with the rat, plus age and motivation variables were analyzed by Thurstone's centroid method of factor analysis and the reference axes rotated orthogonally to maximize the number of zeros in the factorial matrix. Eight

factors adequately account for the intercorrelations. Four factors were tentatively named speed, wildness-timidity, associative or insight learning, and transfer. The other factors were left unidentified.

Many of the tests used involve several factors, or their communalities are so low that they may be considered unreliable. If the factors are to be more clearly isolated, each category must be explored by increasing the number of tests in that category. Modifications of the tests were suggested, which should improve their reliability and at the same time restrict the measurement to one category.

REFERENCES

- (1) DAVIS, FRANK C., AND TOLMAN, EDWARD C. A note on the correlations between two mazes. *J. Comp. Psychol.*, **4**: 125-35. 1924.
- (2) DUNLAP, JACK W. The organization of learning and other traits in chickens. *Comp. Psychol. Monog.*, **9**: 55. 1933.
- (3) HERON, W. T. The inheritance of maze learning ability in rats. *J. Comp. Psychol.*, **19**: 77-90. 1935.
- (4) HONZIK, C. H. Delayed reaction in rats. *Univ. of Calif. Publ. Psychol.*, **4**: 307-318.
- (5) KRECHEVSKY, I. "Hypotheses" vs. chance in the pre-solution period in sensory discrimination-learning. *Univ. of Calif. Publ. Psychol.*, **6**: 27-44.
- (6) LASHLEY, K. S. *Brain Mechanisms and Intelligence*. Chicago: The University of Chicago Press, 1929. Pp. 186.
- (7) LASHLEY, K. S. Studies of cerebral function in learning. XI. The behavior of the rat in latch box situations. *Comp. Psychol. Monog.*, **11**: 1-42. 1935.
- (8) LASHLEY, K. S., AND WILEY, L. E. Studies of cerebral function in learning. IX. Mass action in relation to the number of elements in the problem to be learned. *J. Comp. Neurol.*, **57**: 3-55. 1933.
- (9) LEEPER, R. The reliability and validity of maze experiments with white rats. *Genet. Psychol. Monog.*, **11**: 137-245. 1932.
- (10) LEEPER, R. The rôle of motivation in learning: A study of the phenomenon of differential motivational control of the utilization of habits. *J. Genet. Psychol.*, **46**: 3-40. 1935.
- (11) McCULLOCH, T. L. A study of the cognitive abilities of the white rat with special reference to Spearman's theory of two factors. *Contrib. to Psychological Theory*, **1**: 66. 1935.
- (12) MAIER, N. R. F. Cortical destruction of the posterior part of the brain and its effect on reasoning in rats. *J. Comp. Neurol.*, **56**: 179-214. 1932.
- (13) SHIRLEY, M. Studies of activity. I. Consistency of the revolving drum method of measuring the activity of the rat. *J. Comp. Psychol.*, **8**: 23-38. 1928.

- (14) STONE, C. P. The age factor in animal learning. I. Rats in the problem box and the maze. *Genet. Psychol. Monog.*, **5**: 130. 1929.
- (15) STONE, C. P., AND NYSWANDER, D. B. The reliability of rat learning scores from the multiple-T maze as determined by four different measures. *J. Genet. Psychol.*, **34**: 497-524. 1927.
- (16) STONE, C. P., DARROW, C. W., LANDIS, C., AND HEATH, L. L. *Studies in the Dynamics of Behavior*. Edited by K. S. Lashley. Chicago: The University of Chicago Press, 1932. Pp. 332.
- (17) THORNDIKE, R. L. Organization of behavior in the albino rat. *Genet. Psychol. Monog.*, **17**: 70. 1935.
- (18) THURSTONE, L. L. *The Vectors of Mind*. Chicago: The University of Chicago Press, 1935. Pp. 266.
- (19) TOLMAN, E. C., AND NYSWANDER, D. The reliability and validity of maze measures for rats. *J. Comp. Psychol.*, **7**: 425-60. 1927.
- (20) TRYON, R. C. Genetics of learning ability in rats. *Univ. Calif. Publ. Psychol.*, **4**: 71-89. 1929.
- (21) TRYON, R. C. Studies in individual differences in maze ability. I. The measurement of the reliability of individual differences. *J. Comp. Psychol.*, **11**: 145-70. 1930.
- (22) YERKES, R. M. The heredity of savageness and wildness in rats. *J. Animal Behav.*, **3**: 286-96. 1913.

APPENDIX

Figures 11 and 12 give the distributions of raw scores on 32 of the variables. The dotted lines indicate the frequency distributions after the first 12 cases had been removed, the omission of which was necessary on variables 3, 4, 5, 7, 8, 11, 12, 15, 16, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 33, and 34 for correlations with variables 6, 9, 10, 13, 14, 17, and 18. Correlations with variable 32 were based upon 43 cases, which fact required still further reduction of the distributions. However, these reduced ones are not shown. Their form is similar to the ones given. The distributions of variables 1 and 2 are likewise not shown, as they are somewhat different for each test, and the presentation would require 20 separate charts. The dispersion of variable 1 (age) is small.

The distributions of scores on the tests are interesting. Error scores seem to be more normally distributed than the others. In general, time scores show a bunching at the lower ranges, this fact probably indicating the approach to a physiological limit. Trial scores are, in general, more widely distributed and show a slight bunching at the upper limit. This fact is probably due to the upper limit set by the experimental procedures.



FIG. 11. DISTRIBUTIONS OF RAW SCORES

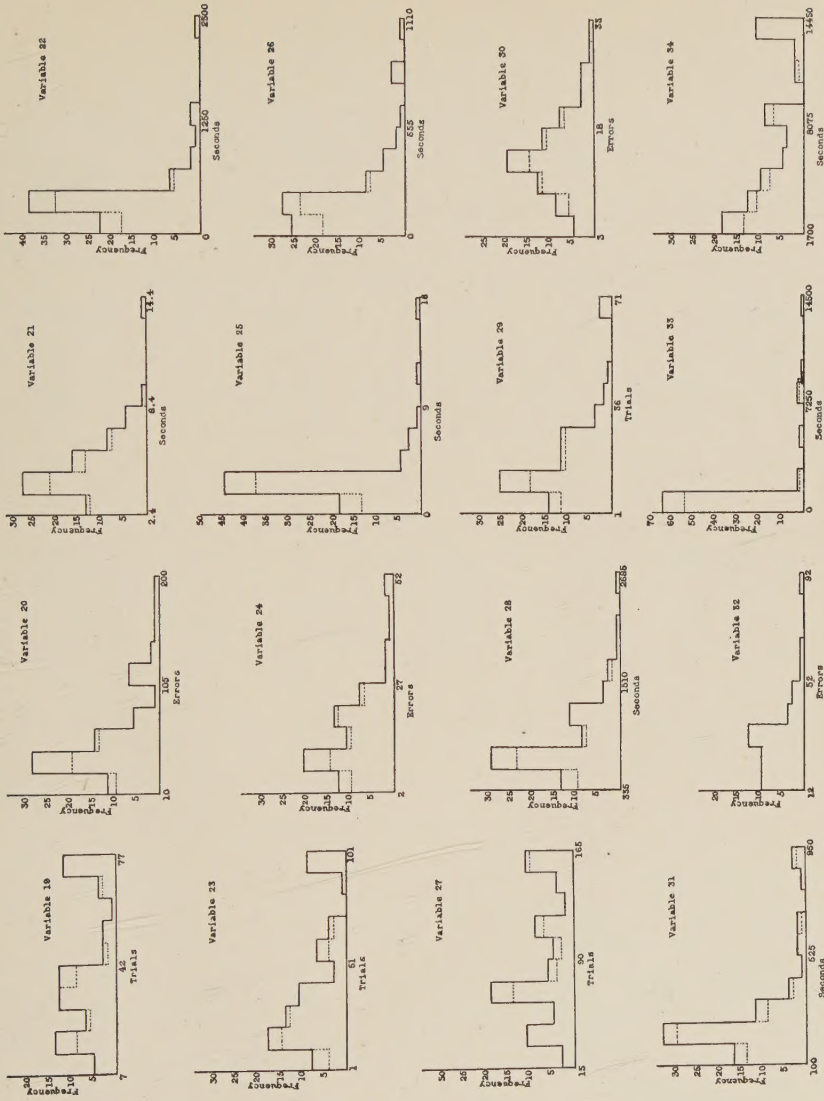


FIG. 12. DISTRIBUTIONS OF RAW SCORES

